Chapter 4

4-1. **(a)** The *millimole* is an amount of a chemical species, such as an atom, an ion, a molecule or an electron. There are

$$6.02\times10^{23}\,\frac{\text{particles}}{\text{mole}} \quad\times\quad 10^{-3}\,\frac{\text{mole}}{\text{millimole}} \quad=\quad 6.02\times10^{20}\,\frac{\text{particles}}{\text{millimole}}$$

(b) The molar mass is the mass in grams of one mole of a chemical species.

(c) The *millimolar mass* is the mass in grams of one millimole of a chemical species.

(d) Parts per million, c_{ppm}, is a term expressing the concentration of dilute solutions. Thus,

$$c_{\text{ppm}} = \frac{\text{mass of solute}}{\text{mass of solution}} \quad\times\quad 10^{6}\,\text{ppm}$$

The units of mass in the numerator and the denominator must be the same.

4-2. The molar species concentration is number of moles of that species contained in one liter of solution. The molar analytical concentration is the total number of moles of a solute in 1 liter of the solution, regardless of the solute's chemical state.

4-3. The liter: $1\text{ L} = \dfrac{1000\text{ mL}}{1\text{ L}} \quad\times\quad \dfrac{1\,\text{cm}^3}{1\text{ mL}}\times\left(\dfrac{1\text{ m}}{100\text{ cm}}\right)^3 \quad=\quad 10^{-3}\text{m}^3$

Molar concentration: $1\text{ M} = \dfrac{1\,\text{mol}}{1\text{ L}} \quad\times\quad \dfrac{1\text{ L}}{10^{-3}\text{m}^3} \quad=\quad \dfrac{1\,\text{mol}}{10^{-3}\text{m}^3}$

4-4. **(a)** $3.2\times10^{8}\,\text{Hz} \quad\times\quad \dfrac{1\text{ MHz}}{10^{6}\,\text{Hz}} \quad=\quad 320\text{ MHz}$

(b) $4.56\times10^{-7}\,\text{g} \quad\times\quad \dfrac{10^{9}\,\text{ng}}{1\text{ g}} \quad=\quad 456\text{ ng}$

(c) $8.43\times10^{7}\,\mu\text{mol} \times \frac{1\text{ mol}}{10^{6}\ \mu\text{mol}} = 84.3\text{ mol}$

(d) $6.5\times10^{10}\,\text{s} \times \frac{1\text{ Gs}}{10^{9}\,\text{s}} = 65\text{ Gs}$

(e) $8.96\times10^{6}\,\text{nm} \times \frac{1\text{ mm}}{10^{6}\,\text{nm}} = 8.96\text{ mm}$

(f) $48{,}000\text{ g} \times \frac{1\text{ kg}}{1000\text{ g}} = 48\text{ kg}$

4-5. For oxygen, for example 15.999 u/atom = 15.999 g/6.022 $\times10^{23}$ atoms = 15.999 g/mol.

So 1 u = 1 g/mol.

Thus, 1g = 1mol u.

4-6. From Pb. 4-5, 1 g = 1 mol u = 6.022×10^{23} u

1 u = 1/12 mass of ^{12}C atom

So 1 kg = 1000 g = 1000× Avogadro's number of u =

1000 × Avogadro's number × 1/12 mass of ^{12}C atom =

1000/12 × Avogadro's number × mass of ^{12}C atom

4-7. $2.92\text{ g } Na_3PO_4 \times \frac{1\text{ mol } Na_3PO_4}{163.94\text{ g}} \times \frac{3\text{ mol } Na^+}{1\text{ mol } Na_3PO_4} \times \frac{6.022\times10^{23}\ Na^+}{1\text{ mol } Na^+} = 3.22 \times 10^{22}\ Na^+$

4-8. $3.41\text{ mol } K_2HPO_4 \times \frac{2\text{ mol } K^+}{1\text{ mol } K_2HPO_4} \times \frac{6.022\times10^{23}\ K^+}{1\text{ mol } K^+} = 4.11\times10^{24}\ K^+$

4-9. **(a)** $8.75\text{ g } B_2O_3 \times \frac{2\text{ mol B}}{1\text{ mol } B_2O_3} \times \frac{1\text{ mol } B_2O_3}{69.62\text{ g } B_2O_3} = 0.251\text{ mol B}$

(b) $167.2\,\text{mg } Na_2B_4O_7\bullet10H_2O \times \frac{1\text{ g}}{1000\,\text{mg}} \times \frac{7\text{ mol O}}{1\text{ mol } Na_2B_4O_7\bullet10H_2O} \times \frac{1\text{ mol } Na_2B_4O_7\bullet10H_2O}{381.37\text{ g}} = 3.07 \times 10^{-3}\,\text{mol O} = 3.07\text{ mmol}$

(c) $4.96\text{ g } Mn_3O_4 \times \frac{1\text{ mol } Mn_3O_4}{228.81\text{ g } Mn_3O_4} \times \frac{3\text{ mol Mn}}{1\text{ mol } Mn_3O_4} = 6.50 \times 10^{-2}\text{ mol Mn}$

(d) $333\text{ mg } CaC_2O_4 \times \frac{1\text{ g}}{1000\text{ mg}} \times \frac{\text{mol } CaC_2O_4}{128.10\text{ g } CaC_2O_4} \times \frac{2\text{ mol C}}{1\text{ mol } CaC_2O_4} = 5.20 \times 10^{-3}\text{ mol C}$

$= 5.20\text{ mmol}$

4-10. **(a)** $850\text{ mg } P_2O_5 \times \frac{1\text{ g}}{1000\text{ mg}} \times \frac{1\text{ mol } P_2O_5}{141.94\text{ g } P_2O_5} \times \frac{1000\text{ mmol}}{1\text{ mol}} \times \frac{2\text{ mol P}}{1\text{ mol } P_2O_5}$

$= 11.98\text{ mmol P}$

(b) $40.0\text{ g } CO_2 \times \frac{1\text{ mol } CO_2}{44.01\text{ g } CO_2} \times \frac{1000\text{ mmol}}{1\text{ mol}} \times \frac{1\text{ mol C}}{1\text{ mol } CO_2} = 909\text{ mmol C}$

(c) $12.92\text{ g } NaHCO_3 \times \frac{1\text{ mol } NaHCO_3}{84.01\text{ g } NaHCO_3} \times \frac{1000\text{ mmol}}{1\text{ mol}} \times \frac{3\text{ mol O}}{1\text{ mol } NaHCO_3} = 461.4\text{ mmol O}$

(d) $57\text{ mg } MgNH_4PO_4 \times \frac{1\text{ g}}{1000\text{ mg}} \times \frac{1\text{ mol } MgNH_4PO_4}{137.32\text{ g } MgNH_4PO_4} \times \frac{1000\text{ mmol}}{1\text{ mol}}$

$\times \frac{1\text{ mol Mg}}{1\text{ mol } MgNH_4PO_4} = 0.42\text{ mmol Mg}$

4-11. **(a)** $\frac{0.0555\text{ mol } KMnO_4}{\text{L}} \times \frac{1000\text{ mmol}}{1\text{ mol}} \times 2.00\text{ L} = 111\text{ mmol } KMnO_4$

(b) $\frac{3.25 \times 10^{-3}\text{ M KSCN}}{\text{L}} \times \frac{1000\text{ mmol}}{1\text{ mol}} \times \frac{\text{L}}{1000\text{ mL}} \times 750\text{ mL}$

$= 2.44\text{ mmol KSCN}$

(c) $\frac{3.33\text{ mg } CuSO_4}{1\text{ L}} \times \frac{1\text{ g}}{1000\text{ mg}} \times \frac{1\text{ mol } CuSO_4}{159.61\text{ g } CuSO_4} \times \frac{1000\text{ mmol}}{1\text{ mol}} \times 3.50\text{ L}$

$= 7.30 \times 10^{-2}\text{ mmol } CuSO_4$

(d) $\frac{0.414\text{ mol KCl}}{1\text{ L}} \times \frac{1000\text{ mmol}}{1\text{ mol}} \times \frac{1\text{ L}}{1000\text{ mL}} \times 250\text{ mL} = 103.5\text{ mmol KCl}$

4-12. **(a)** $\frac{0.320\ \text{mol HClO}_4}{1\ \text{L}} \times \frac{1000\ \text{mmol}}{1\ \text{mol}} \times \frac{1\ \text{L}}{1000\ \text{mL}} \times 226\ \text{mL}$

$= 72.3\ \text{mmol HClO}_4$

(b) $\frac{8.05\times10^{-3}\ \text{mol K}_2\text{CrO}_4}{1\ \text{L}} \times \frac{1000\ \text{mmol}}{1\ \text{mol}} \times 25.0\ \text{L}$

$= 201\ \text{mmol K}_2\text{CrO}_4$

(c) $\frac{6.75\ \text{mg AgNO}_3}{1\ \text{L}} \times \frac{1\ \text{g}}{1000\ \text{mg}} \times \frac{1\ \text{mol AgNO}_3}{169.87\ \text{g AgNO}_3} \times \frac{1000\ \text{mmol}}{1\ \text{mol}} \times 6.00\ \text{L}$

$= 0.238\ \text{mmol AgNO}_3$

(d) $\frac{0.0200\ \text{mol KOH}}{1\ \text{L}} \times \frac{1000\ \text{mmol}}{1\ \text{mol}} \times \frac{1\ \text{L}}{1000\ \text{mL}} \times 537\ \text{mL}$

$= 10.7\ \text{mmol KOH}$

4-13. **(a)** $0.367\ \text{mol HNO}_3 \times \frac{63.01\ \text{g HNO}_3}{1\ \text{mol HNO}_3} \times \frac{1000\ \text{mg}}{1\ \text{g}} = 2.31 \times 10^4\ \text{mg HNO}_3$

(b) $245\ \text{mmol MgO} \times \frac{1\ \text{mol}}{1000\ \text{mmol}} \times \frac{40.30\ \text{g MgO}}{1\ \text{mol MgO}} \times \frac{1000\ \text{mg}}{1\ \text{g}} = 9.87 \times 10^3\ \text{mg MgO}$

(c) $12.5\ \text{mol NH}_4\text{NO}_3 \times \frac{80.04\ \text{g NH}_4\text{NO}_3}{1\ \text{mol NH}_4\text{NO}_3} \times \frac{1000\ \text{mg}}{1\ \text{g}} = 1.00 \times 10^6\ \text{mg NH}_4\text{NO}_3$

(d) $4.95\ \text{mol (NH}_4)_2\text{Ce(NO}_3)_6 \times \frac{548.23\ \text{g (NH}_4)_2\text{Ce(NO}_3)_6}{1\ \text{mol (NH}_4)_2\text{Ce(NO}_3)_6} \times \frac{1000\ \text{mg}}{1\ \text{g}}$

$= 2.71 \times 10^6\ \text{mg (NH}_4)_2\text{Ce(NO}_3)_6$

4-14. **(a)** $3.20\ \text{mol KBr} \times \frac{119.0\ \text{g KBr}}{1\ \text{mol KBr}} = 381\ \text{g KBr}$

(b) $18.9\ \text{mmol PbO} \times \frac{1\ \text{mol}}{1000\ \text{mmol}} \times \frac{223.20\ \text{g PbO}}{1\ \text{mol PbO}} = 4.22\ \text{g PbO}$

(c) $6.02 \text{ mol } MgSO_4 \times \frac{120.37 \text{ g } MgSO_4}{1 \text{ mol } MgSO_4} = 725 \text{ g } MgSO_4$

(d) $10.9 \text{ mmol } Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O \times \frac{1 \text{ mol}}{1000 \text{ mmol}} \times \frac{392.23 \text{ g } Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O}{1 \text{ mol } Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O}$

$= 4.28 \text{ g } Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$

4-15. **(a)** $\frac{0.350 \text{ mol sucrose}}{1 \text{ L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{342 \text{ g sucrose}}{1 \text{ mol sucrose}} \times \frac{1000 \text{ mg}}{1 \text{ g}}$

$\times 16.0 \text{ mL} = 1.92 \times 10^3 \text{ mg sucrose}$

(b) $\frac{3.76 \times 10^{-3} \text{ mol } H_2O_2}{1 \text{ L}} \times \frac{34.02 \text{ g } H_2O_2}{1 \text{ mol } H_2O_2} \times \frac{1000 \text{ mg}}{1 \text{ g}}$

$\times 1.92 \text{ L} = 246 \text{ mg } H_2O_2$

(c) $\frac{2.96 \text{ mg } Pb(NO_3)_2}{1 \text{ L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times 356 \text{ mL}$

$= 1.05 \text{ mg } Pb(NO_3)_2$

(d) $\frac{0.0819 \text{ mol } KNO_3}{1 \text{ L}} \times \frac{101.10 \text{ g } KNO_3}{1 \text{ mol}} \times \frac{1000 \text{ mg}}{1 \text{ g}} \times \frac{1 \text{ L}}{1000 \text{ mL}}$

$\times 5.75 \text{ mL} = 47.6 \text{ mg } KNO_3$

4-16. **(a)** $\frac{0.264 \text{ mol } H_2O_2}{1 \text{ L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{34.02 \text{ g } H_2O_2}{1 \text{ mol } H_2O_2} \times 250 \text{ mL}$

$= 2.25 \text{ g } H_2O_2$

(b) $\dfrac{5.75\times10^{-4}\text{mol benzoic acid}}{1\text{ L}}\times\dfrac{1\text{ L}}{1000\text{ mL}}\times\dfrac{122\text{ g benzoic acid}}{1\text{ mol benzoic acid}}$

$\times\ 37.0\text{ mL} = 2.60\times10^{-3}\text{g benzoic acid}$

(c) $\dfrac{31.7\text{ mg }SnCl_2}{1\text{ L}}\times\dfrac{1\text{ g}}{1000\text{ mg}}\times 4.50\text{ L} = 0.143\text{ g }SnCl_2$

(d) $\dfrac{0.0225\text{ mol }KBrO_3}{1\text{ L}}\times\dfrac{1\text{ L}}{1000\text{ mL}}\times\dfrac{167\text{ g }KBrO_3}{1\text{ mol }KBrO_3}\times 11.7\text{ mL}$

$= 4.40\times10^{-2}\text{g }KBrO_3$

4-17. **(a)** $\text{pNa} = -\log(0.0635 + 0.0403) = -\log(0.1038) = 0.9838$

$\text{pCl} = -\log(0.0635) = 1.197$

$\text{pOH} = -\log(0.0403) = 1.395$

(b) $\text{pBa} = -\log(4.65\times10^{-3}) = 2.333$

$\text{pMn} = -\log(2.54) = -0.405$

$\text{pCl} = -\log(2\times4.65\times10^{-3} + 2\times2.54) = -\log(5.089) = -0.707$

(c)

$\text{pH} = -\log(0.400) = 0.398$

$\text{pCl} = -\log(0.400 + 2\times0.100) = -\log(0.600) = 0.222$

$\text{pZn} = -\log(0.100) = 1.00$

(d)

$\text{pCu} = -\log(5.78\times10^{-2}) = 1.238$

$\text{pZn} = -\log(0.204) = 0.690$

$\text{pNO}_3 = -\log(2\times0.0578 + 2\times0.204) = -\log(0.5236) = 0.281$

(e)

$$pK = -\log(4\times1.62\times10^{-7} + 5.12\times10^{-7}) = -\log(1.16\times10^{-6}) = 5.936$$

$$pOH = -\log(5.12\times10^{-7}) = 6.291$$

$$pFe(CN)_6 = -\log(1.62\times10^{-7}) = 6.790$$

(f)

$$pH = -\log(4.75\times10^{-4}) = 3.32$$

$$pBa = -\log(2.35\times10^{-4}) = 3.63$$

$$pClO_4 = -\log(2\times2.35\times10^{-4} + 4.75\times10^{-4}) = -\log(9.45\times10^{-4}) = 3.02$$

4-18. **(a)** pH = 4.31, $\log[H_3O^+] = -4.31$, $[H_3O^+] = 4.9 \times 10^{-5}$ M

as in part (a)

(b) $[H_3O^+] = 3.3 \times 10^{-5}$ M

(c) $[H_3O^+] = 0.26$ M

(d) $[H_3O^+] = 1.3 \times 10^{-14}$ M

(e) $[H_3O^+] = 2.4 \times 10^{-8}$ M

(f) $[H_3O^+] = 4.8 \times 10^{-6}$ M

(g) $[H_3O^+] = 5.8$ M

(h) $[H_3O^+] = 2.6$ M

4-19. **(a)** pNa = pBr = $-\log(0.0300) = 1.523$

(b) pBa = $-\log(0.0200) = 1.699$; pBr = $-\log(2 \times 0.0200) = 1.398$

(c) pBa = $-\log(5.5 \times 10^{-3}) = 2.26$; pOH = $-\log(2 \times 5.5 \times 10^{-3}) = 1.96$

(d) pH = $-\log(0.020) = 1.70$: pNa = $-\log(0.010) = 2.00$

pCl = −log(0.020 + 0.010) = −log(0.030) = 1.52

(e) pCa = −log(8.7 × 10^{-3}) = 2.06; pBa = −log(6.6 × 10^{-3}) = 2.18

pCl = −log(2 × 8.7 × 10^{-3} + 2 × 6.6 × 10^{-3}) = −log(0.0306) = 1.51

(f) pZn = −log(2.8 × 10^{-8}) = 7.55; pCd = −log(6.6 × 10^{-7}) = 6.18

pNO_3 = −log(2.8 × 10^{-8} + 2 × 6.6 × 10^{-7}) = 5.87

4-20. **(a)** pH = 1.020**;** log[H_3O^+] = −1.020; [H_3O^+] = 0.0955 M

(b) pOH = 0.0025; log[OH^-] = −0.0025; [OH^-] = 0.99 M

(c) pBr = 7.77; [Br^-] = 1.70 × 10^{-8} M

(d) pCa = −0.221; [Ca^{2+}] = 1.66 M

(e) pLi = 12.35; [Li^+] = 4.5 × 10^{-13} M

(f) pNO_3 = 0.034; [NO_3^-] = 0.92 M

(g) pMn = 0.135; [Mn^{2+}] = 0.733 M

(h) pCl = 9.67; [Cl^-] = 2.14 × 10^{-10} M

4-21. **(a)** $1.08\times10^{3}\,\text{ppm Na}^{+}\times\frac{1}{10^{6}\,\text{ppm}}\times\frac{1.02\,\text{g}}{1\,\text{mL}}\times\frac{1000\,\text{mL}}{1\,\text{L}}\times\frac{1\,\text{mol Na}^{+}}{22.99\,\text{g}}=4.79\times10^{-2}\,\text{M Na}^{+}$

$270\,\text{ppm SO}_4^{2-}\times\frac{1}{10^{6}\,\text{ppm}}\times\frac{1.02\,\text{g}}{1\,\text{mL}}\times\frac{1000\,\text{mL}}{1\,\text{L}}\times\frac{1\,\text{mol SO}_4^{3-}}{96.06\,\text{g}}=2.87\times10^{-3}\,\text{M SO}_4^{2-}$

(b) $pNa=-\log(4.79\times10^{-2})=1.320$

$pSO_4=-\log(2.87\times10^{-3})=2.542$

4-22. **(a)** 300 nmol/L = 300 × 10^{-9} mol/L or 300 nM in plasma

2.2 mmol/L = 2.2 × 10^{-3} mol/L or 2.2 mM in whole blood

(b) pHb in plasma = −log(300 × 10^{-9}) = 6.52

pHb in blood = −log(2.2 × 10^{-3}) = 2.66

4-23. (a)

$$\frac{5.76\text{ g KCl•MgCl}_2\text{•6H}_2\text{O}}{2.00\text{ L}}\times\frac{1\text{ mol KCl•MgCl}_2\text{•6H}_2\text{O}}{277.85\text{ g}}=1.04\times10^{-2}\text{M KCl•MgCl}_2\text{•6H}_2\text{O}$$

(b) There is 1 mole of Mg^{2+} per mole of $KCl•MgCl_2$, so the molar concentration of Mg^{2+} is the same as the molar concentration of $KCl•MgCl_2$ or 1.04×10^{-2}M

(c) $$1.04\times10^{-2}\text{M KCl•MgCl}_2\text{•6H}_2\text{O}\times\frac{3\text{ mol Cl}^-}{1\text{ mol KCl•MgCl}_2\text{•6H}_2\text{O}}=3.12\times10^{-2}\text{M Cl}^-$$

(d) $$\frac{5.76\text{ g KCl•MgCl}_2\text{•6H}_2\text{O}}{2.00\text{ L}}\times\frac{1\text{ L}}{1000\text{ mL}}\times100\%=0.288\%\text{ (w/v)}$$

(e) $$\frac{3.12\times10^{-2}\text{ mol Cl}^-}{1\text{ L}}\times\frac{1\text{ L}}{1000\text{ mL}}\times\frac{1000\text{ mmol}}{1\text{ mol}}\times25\text{ mL}=7.8\times10^{-1}\text{ mmol Cl}^-$$

(f) $$1.04\times10^{-2}\text{ M KCl•MgCl}_2\text{•6H}_2\text{O}\times\frac{1\text{ mol K}^+}{1\text{ mol KCl•MgCl}_2\text{•6H}_2\text{O}}\times\frac{39.10\text{ g K}^+}{1\text{ mol K}^+}\times\frac{1000\text{ mg}}{1\text{ g}}$$
$$=\frac{407\text{ mg}}{1\text{ L}}=407\text{ ppm K}^+$$

(g) $pMg = -\log(1.04 \times 10^{-2}) = 1.983$

(h) $pCl = -\log(3.12 \times 10^{-2}) = 1.506$

4-24. (a)

$$\frac{1210\text{ mg } K_3Fe(CN)_6}{775\text{ mL}} \times \frac{1000\text{ mL}}{1\text{ L}} \times \frac{1\text{ g}}{1000\text{ mg}} = \frac{1210\text{ g } K_3Fe(CN)_6}{775\text{ L}}$$

$$\frac{1210\text{ g } K_3Fe(CN)_6}{775\text{ L}} \times \frac{\text{mol } K_3Fe(CN)_6}{329.2\text{ g}} = 4.74\times10^{-3}\text{M } K_3Fe(CN)_6$$

(b) $4.74\times10^{-3}\text{M } K_3Fe(CN)_6 \times \frac{3\text{ mol } K^+}{\text{mol } K_3Fe(CN)_6} = 1.42\times10^{-2}\text{M } K^+$

(c) $4.74\times10^{-3}\text{M } K_3Fe(CN)_6 \times \frac{\text{mol } Fe(CN)_6^{3-}}{\text{mol } K_3Fe(CN)_6} = 4.74\times10^{-3}\text{M } Fe(CN)_6^{3-}$

(d) $\frac{1210\text{mg}K_3Fe(CN)_6}{775\text{mL}} \times \frac{\text{g}}{1000\text{mg}} \times 100\% = 0.156\%\text{ (w/v)}$

(e) $\frac{1.42\times10^{-2}\text{mol } K^+}{\text{L}} \times \frac{\text{L}}{1000\text{ mL}} \times \frac{1000\text{ mmol}K^+}{\text{mol } K^+} \times 50\text{ mL} = 7.1\times10^{-1}\text{mmol } K^+$

(f) $\frac{4.74\times10^{-3}\text{mol } K_3Fe(CN)_6}{\text{L}} \times \frac{\text{mol } Fe(CN)_6^{3-}}{\text{mol } K_3Fe(CN)_6} \times \frac{211.95\text{ g } Fe(CN)_6^{3-}}{\text{mol } Fe(CN)_6^{3-}} \times \frac{1000\text{ mg}}{\text{g}} = \frac{1005\text{ mg}}{\text{L}} Fe(CN)_6^{3-} = 1005\text{ ppm } Fe(CN)_6^{3-}$

(g) $pK = -\log(1.42 \times 10^{-2}) = 1.848$

(h) $pFe(CH)_6 = -\log(4.74 \times 10^{-3}) = 2.324$

4-25. (a) $6.42\%\text{ } Fe(NO_3)_3 = \frac{6.42\text{ g } Fe(NO_3)_3}{100\text{ g solution}} \times \frac{1.059\text{ g}}{\text{mL}} \times \frac{1000\text{ mL}}{1\text{ L}} \times \frac{1\text{ mol } Fe(NO_3)_3}{241.86\text{ g}}$

$= 2.81\times10^{-1}\text{ M } Fe(NO_3)_3 = 0.281\text{ M}$

(b)

$$2.81\times10^{-1}\text{M } Fe(NO_3)_3 = \frac{2.81\times10^{-1}\text{mol } Fe(NO_3)_3}{\text{L}} \times \frac{3\text{ mol } NO_3^-}{1\text{ mol } Fe(NO_3)_3} = 8.43\times10^{-1}\text{M } NO_3^-$$

(c) $\frac{2.81\times10^{-1}\text{mol } Fe(NO_3)_3}{\text{L}} \times \frac{241.86\text{ g } Fe(NO_3)_3}{1\text{ mol}} \times 1\text{ L} = 6.80\times10^{1}\text{g } Fe(NO_3)_3 = 68.0\text{ g}$

4-26. **(a)** $12.5\%\ NiCl_2 = \frac{12.5\ g\ NiCl_2}{100\ g\ solution} \times \frac{1.149\ g}{1\ mL} \times \frac{1000\ mL}{1\ L} \times \frac{1\ mol\ NiCl_2}{129.61\ g} = 1.11\ M\ NiCl_2$

(b) $1.11\ M\ NiCl_2 = \frac{1.11\ mol\ NiCl_2}{L} \times \frac{2\ mol\ Cl^-}{1\ mol\ NiCl_2} = 2.22\ M\ Cl^-$

(c) $\frac{1.11\ mol\ NiCl_2}{L} \times \frac{129.61\ g\ NiCl_2}{mol} \times 1\ L = 1.44 \times 10^2\ g\ NiCl_2$

4-27. **(a)** $\frac{4.75\ g\ C_2H_5OH}{100\ mL\ soln} \times 500\ mL\ soln = 2.38 \times 10^1\ g\ C_2H_5OH$

Weigh 23.8 g ethanol and add enough water to give a final volume of 500 mL

$4.75\%\ (w/w)\ C_2H_5OH = \frac{4.75\ g\ C_2H_5OH}{100\ g\ soln} \times 500\ g\ soln = 2.38 \times 10^1\ g\ C_2H_5OH$

(b) $500\ g\ soln = 23.8\ g\ C_2H_5OH + x\ g\ water$

$x\ g\ water = 500\ g\ soln - 23.8\ g\ C_2H_5OH = 476.2\ g\ water$

Mix 23.8 g ethanol with 476.2 g water

(c) $4.75\%\ (v/v)\ C_2H_5OH = \frac{4.75\ mL\ C_2H_5OH}{100\ mL\ soln}$

$\frac{4.75\ mL\ C_2H_5OH}{100\ mL\ soln} \times 500\ mL\ soln = 2.38 \times 10^1\ mL\ C_2H_5OH$

Dilute 23.8 mL ethanol with enough water to give a final volume of 500 mL.

4-28. **(a)** $\frac{21.0\ g\ C_3H_8O_3}{100\ mL\ soln} \times \frac{1000\ mL}{1\ L} \times 2.50\ L\ soln = 5.25 \times 10^2\ g\ C_3H_8O_3$

Weigh 525 g glycerol and add enough water to give a final volume of 2.50 L.

$21.0\%\ (w/w)\ C_3H_8O_3 = \frac{21.0\ g\ C_3H_8O_3}{100\ g\ soln} \times \frac{1000\ g}{1\ kg} \times 2.50\ kg\ soln = 5.25 \times 10^2\ g\ C_3H_8O_3$

(b) $2.50\ kg\ soln = 0.525\ kg\ C_3H_8O_3 + x\ kg\ water$

$x\ kg\ water = 2.50\ kg\ soln - 0.525\ kg\ C_3H_8O_3 = 1.98\ kg\ water$

Mix 525 g glycerol with 1.98 kg water.

(c)

$$21.0\%\ (v/v)\ C_3H_8O_3 = \frac{21.0\ mL\ C_3H_8O_3}{100\ mL\ soln} \times \frac{1000\ mL}{1\ L} \times 2.50\ L\ soln = 5.25 \times 10^2\ mL\ C_3H_8O_3$$

Dilute 525 mL glycerol with enough water to give a final volume of 2.50 L.

4-29.

$$\frac{6.00\ mol\ H_3PO_4}{L} \times \frac{1\ L}{1000\ mL} \times 750\ mL = 4.50\ mol\ H_3PO_4$$

$$\frac{86\ g\ H_3PO_4}{100\ g\ reagent} \times \frac{1.71\ g\ reagent}{g\ water} \times \frac{g\ water}{mL} \times \frac{1000\ mL}{L} \times \frac{mol\ H_3PO_4}{98.0\ g}$$

$$= \frac{1.50 \times 10^1 mol\ H_3PO_4}{L}$$

$$volume\ 86\%\ (w/w)\ H_3PO_4\ required = 4.50\ mol\ H_3PO_4 \times \frac{L}{1.50 \times 10^1 mol\ H_3PO_4} = 3.00 \times 10^{-1} L$$

4-30.

$$\frac{3.00\ mol\ HNO_3}{L} \times \frac{L}{1000\ mL} \times 900\ mL = 2.70\ mol\ HNO_3$$

$$\frac{70.5\ g\ HNO_3}{100\ g\ reagent} \times \frac{1.42\ g\ reagent}{g\ water} \times \frac{1\ g\ water}{1\ mL} \times \frac{1000\ mL}{1\ L} \times \frac{mol\ HNO_3}{63.0\ g}$$

$$= \frac{1.59 \times 10^1 mol\ HNO_3}{L}$$

$$volume\ 70.5\%\ HNO_3\ required = 2.70\ mol\ HNO_3 \times \frac{L}{1.59 \times 10^1 mol\ HNO_3} = 1.70 \times 10^{-1} L$$

Dilute 170 mL of the concentrated reagent to 900 mL with water.

4-31. **(a)**

$$0.0750\ M\ AgNO_3 = \frac{0.0750\ mol\ AgNO_3}{L}$$

$$= \frac{0.0750\ mol\ AgNO_3}{L} \times \frac{169.87\ g\ AgNO_3}{1\ mol} \times \frac{1\ L}{1000\ mL} \times 500\ mL$$

$$= 6.37\ g\ AgNO_3$$

Dissolve 6.37 g $AgNO_3$ in enough water to give a final volume of 500 mL.

(b)

$$\frac{0.285\ \text{mol HCl}}{\text{L}} \times 1\ \text{L} = 0.285\ \text{mol HCl}$$

$$0.285\ \text{mol HCl} \times \frac{1\ \text{L}}{6.00\ \text{mol HCl}} = 4.75\times10^{-2}\ \text{L HCl}$$

Take 47.5 mL of the 6.00 M HCl and dilute to 1.00 L with water.

(c)

$$\frac{0.0810\ \text{mol K}^+}{\text{L}} \times \frac{1\ \text{L}}{1000\ \text{mL}} \times 400\ \text{mL} = 3.24\times10^{-2}\ \text{mol K}^+$$

$$3.24\times10^{-2}\ \text{mol K}^+ \times \frac{1\ \text{mol K}_4\text{Fe(CN)}_6}{4\ \text{mol K}^+} \times \frac{368.43\ \text{g K}_4\text{Fe(CN)}_6}{\text{mol}} = 2.98\ \text{g K}_4\text{Fe(CN)}_6$$

Dissolve 2.98 g $K_4Fe(CN)_6$ in enough water to give a final volume of 400 mL.

(d)

$$\frac{3.00\ \text{g BaCl}_2}{100\ \text{mL soln}} \times 600\ \text{mL} = 1.8\times10^{1}\ \text{g BaCl}_2$$

$$1.8\times10^{1}\ \text{g BaCl}_2 \times \frac{1\ \text{mol BaCl}_2}{208.23\ \text{g}} \times \frac{\text{L}}{0.400\ \text{mol BaCl}_2} = 2.16\times10^{-1}\ \text{L}$$

Take 216 mL of the 0.400 M $BaCl_2$ solution and dilute to 600 mL with water

(e)

$$\frac{0.120\ \text{mol HClO}_4}{\text{L}} \times 2.00\ \text{L} = 0.240\ \text{mol HClO}_4$$

$$\frac{71\ \text{g HClO}_4}{100\ \text{g reagent}} \times \frac{1.67\ \text{g reagent}}{1\ \text{g water}} \times \frac{1\ \text{g water}}{1\ \text{mL}} \times \frac{1000\ \text{mL}}{1\ \text{L}} \times \frac{\text{mol HClO}_4}{100.46\ \text{g}}$$

$$= \frac{1.18\times10^{1}\ \text{mol HClO}_4}{\text{L}}$$

$$\text{volume 71\% (w/w) HClO}_4\ \text{required} = 0.240\ \text{mol HClO}_4 \times \frac{\text{L}}{1.18\times10^{1}\ \text{mol HClO}_4} = 2.03\times10^{-2}\ \text{L}$$

Take 20.3 mL of the concentrated reagent and dilute to 2.00 L with water.

$$60 \text{ ppm } Na^+ = \frac{60 \text{ mg } Na^+}{\text{L soln}}$$

(f)

$$\frac{60 \text{ mg } Na^+}{\text{L soln}} \times 9.00 \text{ L} = 5.4\times10^2 \text{ mg } Na^+$$

$$5.4\times10^2 \text{ mg } Na^+ \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ mol } Na^+}{22.99 \text{ g}} = 2.35\times10^{-2} \text{ mol } Na^+$$

$$2.35\times10^{-2} \text{ mol } Na^+ \times \frac{1 \text{ mol } Na_2SO_4}{2 \text{ mol } Na^+} \times \frac{142.04 \text{ g } Na_2SO_4}{1 \text{ mol}} = 1.7 \text{ g } Na_2SO_4$$

Dissolve 1.7 g Na_2SO_4 in enough water to give a final volume of 9.00 L.

4-32. **(a)**

$$\frac{0.0500 \text{ mol } KMnO_4}{\text{L}} \times 5.00 \text{ L} \times \frac{158.03 \text{ g } KMnO_4}{1 \text{ mol}} = 3.95\times10^1 \text{ g } KMnO_4$$

Dissolve 39.5 g $KMnO_4$ in enough water to give a final volume of 5.00 L.

(b)

$$\frac{0.250 \text{ mol } HClO_4}{\text{L}} \times 4.00 \text{ L} = 1.00 \text{ mol } HClO_4$$

$$1.00 \text{ mol } HClO_4 \times \frac{1 \text{ L}}{8.00 \text{ mol reagent}} = 1.25\times10^{-1} \text{ L reagent}$$

Take 125 mL of the 8.00 M reagent and dilute a final of volume of 4.00 L with water.

(c)

$$\frac{0.0250 \text{ mol } I^-}{\text{L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times 400 \text{ mL} = 1.00 \times 10^{-2} \text{ mol } I^-$$

$$1.00 \times 10^{-2} \text{ mol } I^- \times \frac{1 \text{ mol } MgI_2}{2 \text{ mol } I^-} \times \frac{278.11 \text{ g } MgI_2}{1 \text{ mol}} = 1.39 \text{ g } MgI_2$$

Dissolve 1.39 g MgI_2 in enough water to give a final volume of 400 mL

$$1.00\% \text{ (w/v) } CuSO_4 = \frac{1.00 \text{ g } CuSO_4}{100 \text{ mL soln}}$$

(d)

$$\frac{1.00 \text{ g } CuSO_4}{100 \text{ mL soln}} \times 200 \text{ mL} = 2.00 \text{ g } CuSO_4$$

$$2.00 \text{ g } CuSO_4 \times \frac{1 \text{ mol } CuSO_4}{159.60 \text{ g}} \times \frac{\text{L}}{0.365 \text{ mol } CuSO_4} = 3.43\times10^{-2} \text{ L}$$

Take 34.3 mL of the 0.365 M $CuSO_4$ and dilute to a final volume of 200 mL with water

(e)

$$\frac{0.215\ \text{mol NaOH}}{\text{L}} \times 1.50\ \text{L} = 0.322\ \text{mol NaOH}$$

$$50\%\ \text{(w/w) NaOH} = \frac{50\ \text{g NaOH}}{100\ \text{g reagent}}$$

$$\frac{50\ \text{g NaOH}}{100\ \text{g reagent}} \times \frac{1.525\ \text{g reagent}}{1\ \text{g water}} \times \frac{1\ \text{g water}}{1\ \text{mL}} \times \frac{1000\ \text{mL}}{1\ \text{L}} \times \frac{\text{mol NaOH}}{40.00\ \text{g}}$$

$$= \frac{1.9\times10^{1}\ \text{mol NaOH}}{\text{L}}$$

$$\text{volume 50\% (w/w) NaOH required} = 0.322\ \text{mol NaOH} \times \frac{\text{L}}{1.9\times10^{1}\ \text{mol NaOH}} = 1.7\times10^{-2}\ \text{L}$$

Take 17 mL of the concentrated reagent and dilute to a final volume of 1.50 L

with water

(f)

$$12.0\ \text{ppm } K^{+} = \frac{12\ \text{mg } K^{+}}{\text{L soln}}$$

$$\frac{12\ \text{mg } K^{+}}{\text{L soln}} \times 1.50\ \text{L} = 1.8\times10^{1}\ \text{mg } K^{+}$$

$$1.8\times10^{1}\ \text{mg } K^{+} \times \frac{1\ \text{g}}{1000\ \text{mg}} \times \frac{1\ \text{mol } K^{+}}{39.10\ \text{g}} = 4.60\times10^{-4}\ \text{mol } K^{+}$$

$$4.60\times10^{-4}\ \text{mol } K^{+} \times \frac{1\ \text{mol } K_4Fe(CN)_6}{4\ \text{mol } K^{+}} \times \frac{368.35\ \text{g } K_4Fe(CN)_6}{1\ \text{mol}} = 4.24\times10^{-2}\ \text{g } K_4Fe(CN)_6$$

Dissolve 42.4 mg $K_4Fe(CN)_6$ in enough water to give a final volume of 1.50 L.

4-33.

$$\frac{0.250\ \text{mol } La^{3+}}{\text{L}} \times \frac{1\ \text{L}}{1000\ \text{mL}} \times 50.0\ \text{mL} = 1.25\times10^{-2}\ \text{mol } La^{3+}$$

$$0.302\ \text{M } IO_3^{-} = \frac{0.302\ \text{mol } IO_3^{-}}{1\ \text{L}} \times \frac{1\ \text{L}}{1000\ \text{mL}} \times 75.0\ \text{mL} = 2.27\times10^{-2}\ \text{mol } IO_3^{-}$$

Because each mole of $La(IO_3)_3$ requires three moles IO_3^-, IO_3^- is the limiting reagent.

Thus,

$$2.27\times10^{-2}\,\text{mol } IO_3^- \times \frac{1\text{ mol } La(IO_3)_3}{3\text{ mol } IO_3^-} \times \frac{663.6\text{ g } La(IO_3)_3}{1\text{ mol}} = 5.01\text{ g } La(IO_3)_3 \text{ formed}$$

4-34

$$\frac{0.125\text{ mol } Pb^{2+}}{\text{L}} \times \frac{1\text{ L}}{1000\text{ mL}} \times 200\text{ mL} = 2.50\times10^{-2}\,\text{mol } Pb^{2+}$$

$$\frac{0.175\text{ mol } Cl^-}{\text{L}} \times \frac{1\text{ L}}{1000\text{ mL}} \times 400\text{ mL} = 7.00\times10^{-2}\text{ mol } Cl^-$$

Because each mole of $PbCl_2$ requires two moles Cl^-, Pb^{2+} is the limiting reagent. Thus,

$$2.50\times10^{-2}\text{ mol } Pb^{2+} \times \frac{1\text{ mol } PbCl_2}{1\text{ mol } Pb^{2+}} \times \frac{278.10\text{ g } PbCl_2}{1\text{ mol}} = 6.95\text{ g } PbCl_2 \text{ formed}$$

4-35. A balanced chemical equation can be written as:

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2(g)$$

(a)

$$0.2220\text{ g } Na_2CO_3 \times \frac{1\text{ mol } Na_2CO_3}{105.99\text{ g}} = 2.094\times10^{-3}\,\text{mol } Na_2CO_3$$

$$\frac{0.0731\text{ mol HCl}}{\text{L}} \times \frac{1\text{ L}}{1000\text{ mL}} \times 100.0\text{ mL} = 7.31\times10^{-3}\text{ mol HCl}$$

Because one mole of CO_2 is evolved for every mole Na_2CO_3 reacted, Na_2CO_3 is the limiting reagent. Thus

$$2.094\times10^{-3}\text{ mol } Na_2CO_3 \times \frac{1\text{ mol } CO_2}{1\text{ mol } Na_2CO_3} \times \frac{44.00\text{ g } CO_2}{1\text{ mol}} = 9.214\times10^{-2}\text{ g } CO_2 \text{ evolved}$$

(b)

$$\text{amnt HCl left} = 7.31\times10^{-3}\,\text{mol} - (2\times 2.094\times10^{-3}\,\text{mol}) = 3.12\times10^{-3}\,\text{mol}$$

$$\frac{3.12\times10^{-3}\ \text{mol HCl}}{100.0\ \text{mL}}\times\frac{1000\ \text{mL}}{1\ \text{L}} = 3.12\times10^{-2}\ \text{M HCl}$$

4-36. A balanced chemical equation can be written as

$$Na_3PO_4 + 3HgNO_3 \rightarrow 3NaNO_3 + Hg_3PO_4$$

(a)

$$\frac{0.3757\ \text{mol } Na_3PO_4}{\text{L}}\times\frac{1\ \text{L}}{1000\ \text{mL}}\times 25.0\ \text{mL} = 9.39\times10^{-3}\ \text{mol } Na_2PO_4$$

$$\frac{0.5151\ \text{mol } HgNO_3}{\text{L}}\times\frac{1\ \text{L}}{1000\ \text{mL}}\times 100.0\ \text{mL} = 5.151\times10^{-2}\ \text{mol } HgNO_3$$

The limiting reagent is Na_2PO_4. Thus,

$$9.39\times10^{-3}\ \text{mol } Na_2PO_4 \times \frac{1\ \text{mol } Hg_3PO_4}{1\ \text{mol } Na_3PO_4} \times \frac{696.74\ \text{g } Hg_3PO_4}{\text{mol}} = 6.54\ \text{g } Hg_3PO_4 \text{ formed}$$

(b)

$$\text{mol } HgNO_3 \text{ unreacted} = 5.151\times10^{-2}\ \text{mol} - (3\times 9.39\times10^{-3}\,\text{mol}) = 2.33\times10^{-2}\,\text{mol}$$

$$\frac{2.33\times10^{-2}\,\text{mol } HgNO_3}{125.0\ \text{mL}}\times\frac{1000\ \text{mL}}{1\ \text{L}} = 1.87\times10^{-1}\,\text{M } HgNO_3$$

4-37 A balanced chemical equation can be written as:

$$Na_2SO_3 + 2HClO_4 \rightarrow 2NaClO_4 + H_2O + SO_2(g)$$

(a)

$$0.3132\ \text{M } Na_2SO_3 = \frac{0.3132\ \text{mol } Na_2SO_3}{\text{L}}\times\frac{\text{L}}{1000\ \text{mL}}\times 75\ \text{mL} = 2.3\times10^{-2}\text{mol } Na_2SO_3$$

$$0.4025\ \text{M } HClO_4 = \frac{0.4025\ \text{mol } HClO_4}{\text{L}}\times\frac{\text{L}}{1000\ \text{mL}}\times 150.0\ \text{mL} = 6.038\times10^{-2}\text{mol } HClO_4$$

Because one mole SO_2 is evolved per mole Na_2SO_3, Na_2SO_3 is the limiting reagent.

Thus,

$$2.3\times10^{-2}\,\text{mol } Na_2SO_3\times\frac{\text{mol } SO_2}{\text{mol } Na_2SO_3}\times\frac{64.06\text{ g } SO_2}{\text{mol}} = 1.5\text{ g } SO_2 \text{ evolved}$$

(b)

$$\text{mol } HClO_4 \text{ unreacted} = (6.038\times10^{-2}\,\text{mol} - (2\times 2.3\times10^{-2}) = 1.4\times10^{-2}\text{ mol}$$

$$\frac{1.4\times10^{-2}\,\text{mol } HClO_4}{225\text{ mL}}\times\frac{1000\text{ mL}}{\text{L}} = 6.4\times10^{-2}\text{ M } HClO_4 = 0.064\text{ M}$$

4-38. A balanced chemical equation can be written as:

$$MgCl_2 + Na_3PO_4 + NH_4^+ \rightarrow MgNH_4PO_4(s) + 3Na^+ + 2Cl^-$$

$$\frac{1.000\text{ g } MgCl_2}{100\text{ mL}}\times 200.0\text{ mL}\times\frac{1\text{ mol } MgCl_2}{95.21\text{ g}}$$

$$= 2.101\times10^{-2}\text{ mol } MgCl_2$$

$$\frac{0.1753\,\text{mol } Na_2PO_4}{\text{L}}\times\frac{\text{L}}{1000\text{ mL}}\times 40.0\text{ mL} = 7.01\times10^{-3}\text{ mol } Na_2PO_4\ Na_2PO_4 \text{ is the}$$

limiting reagent. Thus,

$$\text{amnt } MgCl_2 \text{ unreacted} = (2.101\times10^{-2} - 7.01\times10^{-3}) = 1.40\times10^{-2}\text{ mol}$$

$$\frac{1.40\times10^{-2}\,\text{mol } MgCl_2}{240.0\text{ mL}}\times\frac{1000\text{ mL}}{1\text{ L}} = 5.83\times10^{-2}\text{ M } MgCl_2$$

4-39. A balanced chemical equation can be written as:

$$AgNO_3 + KI \rightarrow AgI(s) + KNO_3$$

$$24.31\text{ ppt KI}\times\frac{1}{10^3\text{ppt}}\times\frac{1\text{ g}}{1\text{ mL}}\times 200.0\text{ mL}\times\frac{1\text{ mol KI}}{166.0\text{ g}} = 2.93\times10^{-2}\text{ mol KI}$$

$$2.93\times10^{-2}\text{ mol KI}\times\frac{1\text{ mol } AgNO_3}{1\text{ mol KI}}\times\frac{1\text{ L}}{0.0100\text{ mol } AgNO_3} = 2.93\text{ L } AgNO_3$$

2.93 L of 0.0100 M $AgNO_3$ would be required to precipitate I^- as AgI.

4-40. A balanced chemical equation can be written as

$$3Ba(NO_3)_2 + Al_2(SO_4)_3 \rightarrow 3BaSO_4 + 2Al^{+3} + 6NO_3^-$$

(a)

$$480.4 \text{ ppm } Ba(NO_3)_2 \times \frac{1}{10^6 \text{ppm}} \times \frac{1 \text{ g}}{1 \text{ mL}} \times 750.0 \text{ mL} \times \frac{\text{mol } Ba(NO_3)_2}{261.34 \text{ g}}$$

$$= 1.38 \times 10^{-3} \text{ mol } Ba(NO_3)_2$$

$$\frac{0.03090 \text{ mol } Al_2(SO_4)_3}{\text{L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times 200.0 \text{ mL}$$

$$= 6.18 \times 10^{-3} \text{ mol } Al_2(SO_4)_3$$

$Ba(NO_3)_2$ is the limiting reagent. Thus,

$$1.38 \times 10^{-3} \text{mol } Ba(NO_3)_2 \times \frac{3 \text{ mol } BaSO_4}{3 \text{ mol } Ba(NO_3)_2} \times \frac{233.39 \text{ g } BaSO_4}{1 \text{ mol}} = 3.22 \times 10^{-1} \text{ g } BaSO_4 \text{ formed}$$

(b) Since 3 moles of $Ba(NO_3)_2$ react with 1 mole of $Al_2(SO_4)_3$,

$$\text{amnt } Al_2(SO_4)_3 \text{ unreacted} = (6.18 \times 10^{-3} \text{ mol} - (1/3 \times 1.38 \times 10^{-3} \text{mol}) = 5.72 \times 10^{-3} \text{ mol}$$

$$\frac{5.72 \times 10^{-3} \text{mol } Al_2(SO_4)_3}{950.0 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 6.02 \times 10^{-3} \text{ M } Al_2(SO_4)_3$$